Fresh water content variability in the Arctic Ocean
in a global ocean-sea ice-atmosphere model

D. Salas y Mélia, METEO-France/CNRM-GAME, 42, av. Coriolis, Toulouse, France, david.salas@meteo.fr

Abstract

A global coupled system, CNRM-CM3, including Arpege 3 AGCM (CNRM, T42), OPA 8 OGCM (LODYC, Paris, about 1.5° resolution), Gelato 2 dynamic (elastic-viscous plastic) and thermodynamic sea ice model (CNRM), MOBIDIC ozone chemistry model (CNRM) and TRIP river routing scheme (T. Oki, university of Tokyo, Japan) was developed and run to provide climate simulation data for IPCC-AR4 (Salas-Mélia et al., 2005). Among these different experiments, a 500-yr pre-industrial experiment (1860 greenhouse gases and aerosols estimated conditions) was analyzed in the Arctic and the North Atlantic regions. Only the last 400 years of this simulation were considered, as bottom water masses still drifted significantly during the initial 100-yr period. In this study we investigated the reasons for the simulated significant fresh water content variability, by quantifying the contributions of the different terms involved.

1. Experiment set up

In order to obtain an initial state for CNRM-CM3 corresponding to a preindustrial quasi-equilibrium of the climate system, a spin-up experiment was carried out. The ocean and sea ice were initially at rest. Temperature, salinity and the concentration of sea ice were initialized from climatological data representing January 1st conditions (see Salas-Mélia et al., 2005, http://www.cnrm.meteo.fr/scenario2004/). Sea ice thickness in the Arctic and the Antarctic were respectively set equal to constant values of 3 and 1m. The concentrations of all atmospheric forcing agents were estimates for 1860, considered as typical for preindustrial conditions. A 3D relaxation of ocean salinity and temperature fields toward Levitus climatology was applied during the first 10 years of the spin-up. During the following 20 years the model was run with surface relaxation only. Then CNRM-CM3 was span-up for 70 years without any restoring term. During this experiment, sea ice and surface ocean reached a steady state after respectively about 15 and 30 years. By the end of this simulation, only bottom water masses were still drifting and the 500-yr preindustrial experiment began (denoted as PIcntrl). During the first 100 years of PIcntrl, deep water masses in the Arctic and North Atlantic drifted significantly, primarily due to increased deep ocean convection in the North Atlantic.

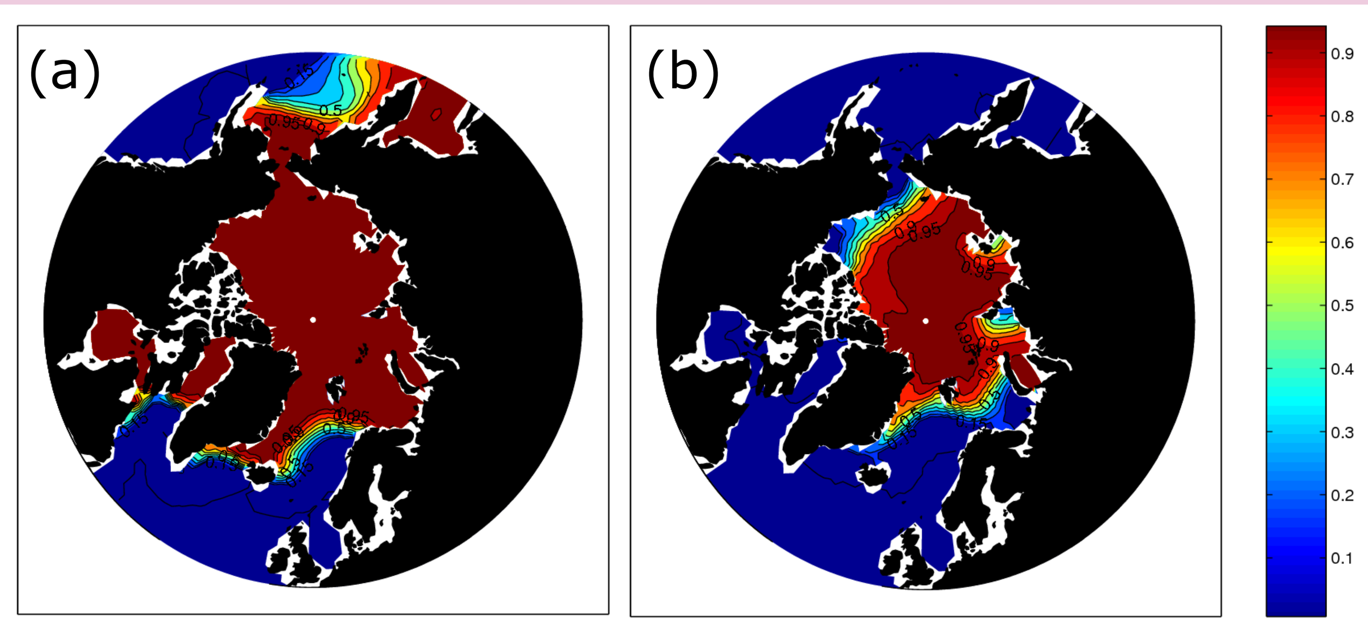
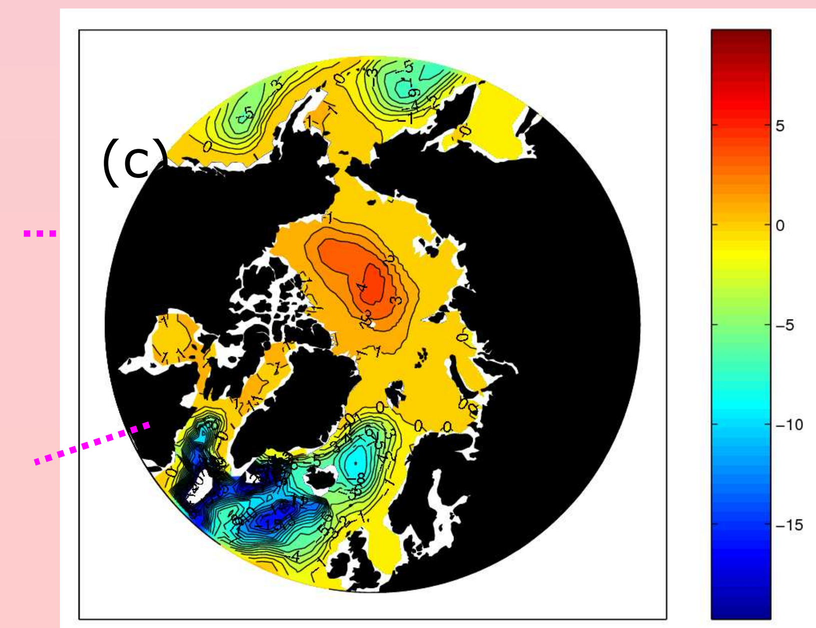


Fig.1: model climatology, yr 101-500: (a), (b) sea ice concentration, march and sep. ; (c) mean barotropic stream function



Arctic Fresh Water Sources / Sinks	Km³/yr
Runoff	2024
Precipitation minus evaporation	464
Ice export through Fram Strait	-983
Water export through Fram Strait	-593
Water export from Barents Sea	-512
Ice export to Barents Sea	-934
Water import from Bering Sea	1070
Ice export through Bering Strait	-284
Total	**252**

Fig.2: Arctic fresh water sources and sinks. Reference salinity value is 34.8 psu. Boundaries of the Arctic Ocean as defined in this study are shown by the magenta dotted lines in Fig.1c.

2. Model climatology

The simulated climate is globally 1°C too cold, and this also holds for the Arctic. The ice edge is located slightly too far south in all seasons, except in Davis Strait. However sea ice is probably too thin (just over 2m). Due to weak dynamics (see Fig. 1c) and too thin ice in the Fram Strait area, the ice and water fluxes there are small, compared to current estimates.

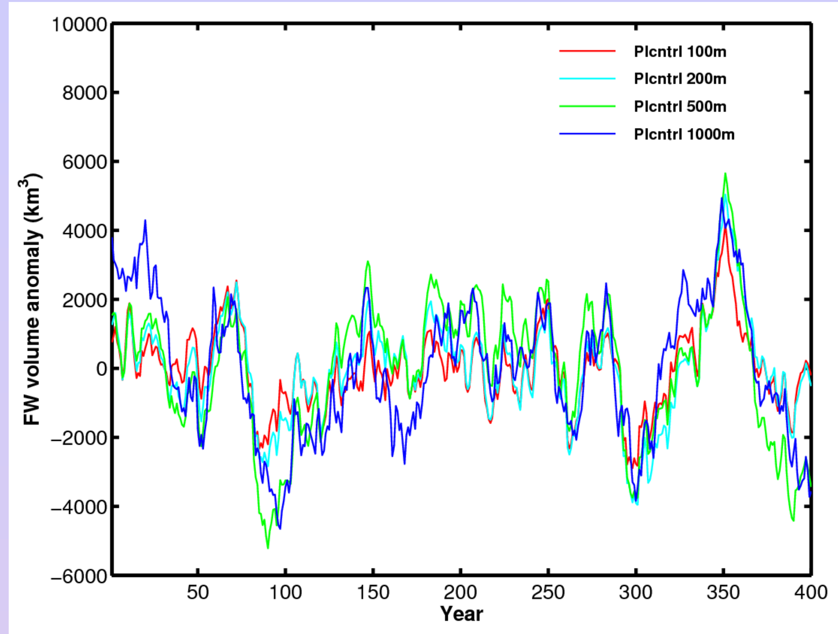


Fig.3: Fresh water content anomalies in the top 100, 200, 500 and 1000m layers of the Arctic Ocean. Reference salinity value is 34.8 psu.

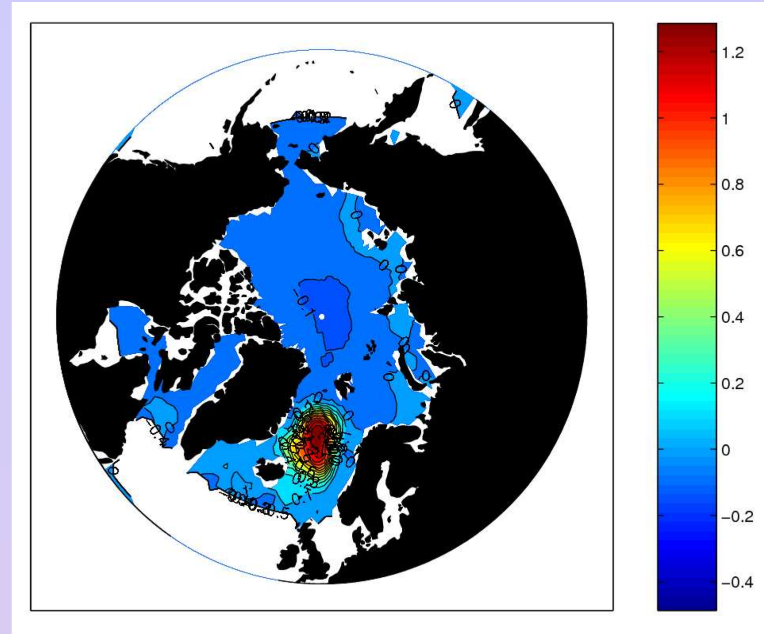


Fig.4: First EOF of the monthly barotropic stream function in Picntrl. Positive contours represent cyclonic circulation.

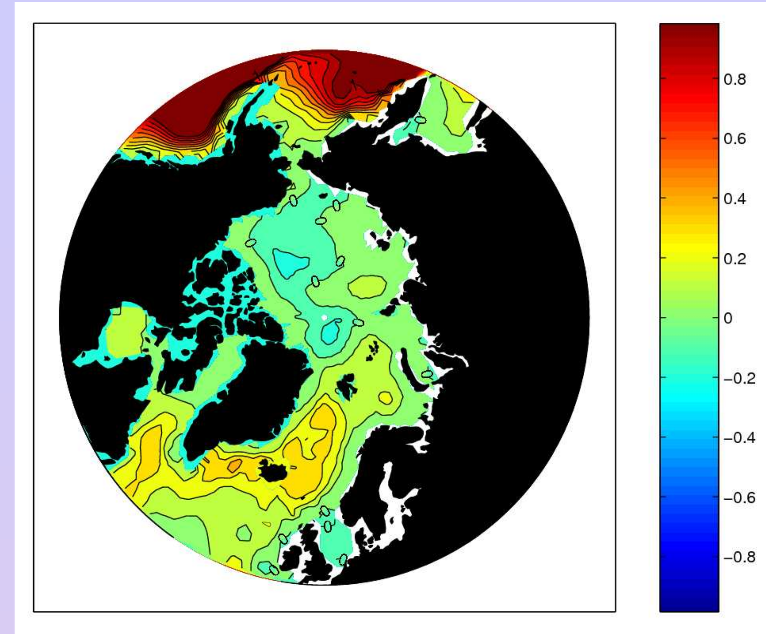


Fig.5: Same as Fig.4, but for a global coupled ocean-sea ice model, forced by ERA40 reanalysis.

3. Fresh water content anomalies and barotropic flow variability

The freshwater anomalies show coherent variations above all levels (Fig.3), and can be relatively large for a few decades (yrs 80-100, around yr 300, yrs 340-360). In contrast with e.g. Häkkinen and Proshutinsky (2004), they could not be explained by the variability of the barotropic streamfunction across the North Atlantic and the Arctic, as the cyclonic monopole pattern spanning these regions is not present in our coupled model. An ocean-sea ice model, very similar to the one in CNRM-CM3 (but on a slightly different grid of equivalent resolution) was forced by ERA40 reanalysis on the 1958-2001 period and showed a more realistic barotropic flow variability pattern. This experiment confirmed that the circulation patterns as modelled by the atmospheric component in CNRM-CM3 are too zonal in the north-eastern Atlantic and in the Arctic.

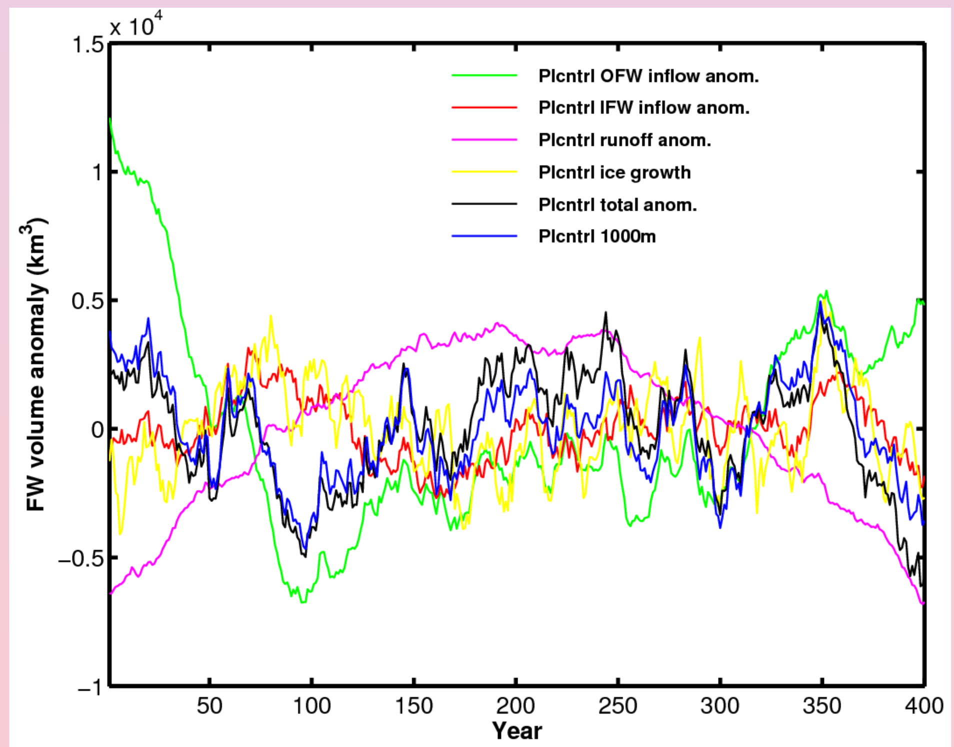


Fig.6: Fresh water content anomalies in the 1000m layer of the Arctic Ocean + in sea ice (blue) and their reconstruction from the different fresh water sinks and sources (other curves).

4. Conclusion: Identifying the different contributions in the variability of fresh water anomalies

It can be noticed from Fig.6 that, even if the contributions of sea ice thermodynamic growth and sea ice outflow through the boundaries to interannual variability is not negligible, the anomalies of oceanic fresh water baroclinic inflow generally explain most of the fresh water content anomalies in the topmost 1000m of the Arctic Ocean. An initial phase of adjustment of the ocean's bottom layers prevails over the first 50 years of the simulation. The runoff anomalies are characterized by long term drifts and does not show any interannual to multidecadal variability.

Acknowledgements

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